HEAT EXCHANGER PLATE AND PLATE HEAT EXCHANGER COMPRISING SUCH PLATES

FIELD OF THE INVENTION

The present invention relates to a heat exchanger plate comprising a number of turbulence-promoting protuberances which project from the plane of the heat exchanger plate. The invention also relates to a plate heat exchanger comprising such plates.

BACKGROUND ART

Plate heat exchangers are frequently used in the food industry for, for instance, processes for heat treatment of milk and juice. In its simplest embodiment, a plate heat exchanger comprises a number of corrugated plates with intermediate packings. The plates are pressed together in a stand with tube connections for inlet and outlet of two fluids, i.e. the fluid that is to be tempered and the fluid that is used for tempering. The two fluids are made to flow on both sides of the plates so that one fluid flows between every second pair of plates and the other fluid flows between the adjoining pair of plates. The number of plates and their size depend, among other things, on flow velocity, physical properties of the fluids, pressure drop and inlet and outlet temperature of the fluids.

The corrugation of the plates generates a turbulent flow through the major part of the gap cross-section between two plates and also a large specific surface, which causes a high heat transfer capacity. A very large number of documents are to be found in the field, which demonstrates an intensive development of different corrugations.

The document US 4,569,391 discloses, for example, a plate heat exchanger, in which each plate is provided with hemispherical protuberances. The protuberances in

a first plate are arranged to abut, with their convex circumferential surface, between the protuberances in a second adjoining plate.

Another variant is disclosed in US 2,306,526. This document discloses a plate heat exchanger, in which a first plate with hemispherical protuberances is arranged to abut against a second plate with corresponding protuberances in such a manner that the protuberances in the first and the second plate are oriented in diametrically opposite directions.

A third document US 2,281,754 discloses a plate heat exchanger, in which the plates comprise hemispherical protuberances. The plates are arranged relative to each other so that the protuberances in a first plate abut against a flat portion on the rear side of a second plate.

A common feature of these solutions is that the plates comprise hemispherical protuberances for generating a turbulent flow through the major part of the gap cross-section between two adjoining plates. However, it is desirable to achieve a further improvement of the heat transfer capacity.

OBJECTS OF THE PRESENT INVENTION

The object of the present invention is to provide a further development of, and an alternative solution to, the previously known geometries of heat exchanger plates.

Another object is to obtain heat exchanger plates which contribute to increased turbulence and promote the break-up of laminar boundary layers.

A further object of the invention is to provide an increased specific surface of heat exchanger plates.

Yet another object of the invention is to provide a plate heat exchanger with improved heat transfer properties.

SUMMARY OF THE INVENTION

To achieve the above-mentioned and further objects not mentioned, which will appear from the following description, the present invention concerns a heat exchanger plate having the features defined in claim 1. The invention also concerns according to claim 9 a plate heat exchanger comprising such heat exchanger plates.

More specifically, a heat exchanger plate comprising a number of turbulence-promoting protuberances which project from the plane of the heat exchanger plate is provided. The heat exchanger plate is characterised in that the protuberances have a surface profile for promoting break-up of laminar boundary layers, and that the surface profile consists of spherical or ellipsoid segments.

In hydrodynamics, the term "laminar boundary layer" is often used. The term relates in general, and in this application, to that part of a flowing volume of fluid which flows so close to a boundary surface that the viscous force dominates over the other forces. The thus low flow velocity implies that this part of the fluid volume next to the boundary surface flows in a laminar manner, while the remaining part of the fluid volume flows in a turbulent manner. With plate heat exchangers, such laminar boundary layers thus arise along the surfaces of the heat exchanger plates which together build up a plate heat exchanger. The surface profile, used in the invention, of the circumferential surfaces of the protuberances thus creates a "surface roughness" which promotes break-up of the laminar boundary layers. In other words, the break-up promotes the production of a turbulent flow in the fluid volume through all of, or the major part of, a gap cross-section defined by two heat exchanger plates. The fluid volume through all of, or the major part of, the gap cross-section flowing turbulently results in very efficient mixing of the fluid and, thus, efficient tempering of the fluid to be tempered and also efficient heat transfer from/to the fluid

that is used for tempering. The fact that the surface profile consists of spherical or ellipsoid segments contributes to the heat exchanger plate not having any sharp edges or corners than can create dead spaces which conventional cleaning methods cannot reach. This is very important from the aspects of food hygiene since dead spaces may cause undesirable growth of bacteria and other organisms. The soft geometry is also favourable from the aspect of forming technology.

It should be appreciated that, depending on how the respective heat exchanger plates are made, the front and rear side thereof will have different profiles. A pressed heat exchanger plate has, for instance, one side with a concave profile and one side with a convex profile. The flow pattern of the fluids will thus be different on the two sides. Which fluid is in contact with which side of the heat exchanger plate will be determined from case to case, as will also the geometry and profile depth of the protuberances and the surface profile respectively.

The surface profile also increases the specific surface, which further favours the tempering of the fluid that is to be tempered, and also favours the heat transfer to/from the fluid that is used for tempering.

By specific surface is meant each of the surfaces which in operation are exposed to the fluids flowing through the plate heat exchanger. The front and rear sides of the heat exchanger plate thus have their specific surface. The increased turbulence in combination with the increased specific surfaces increases the total heat transfer capacity of the plate heat exchanger, which enables more rapid flows and, thus, a higher production capacity.

In a preferred embodiment, the heat exchanger plate is, together with a plurality of identical heat exchanger plates, stackable in such a manner that the protuberances in a first heat exchanger plate are partially accommodated in the protuberances in a second heat exchanger plate.

It is also preferred for the protuberances to be symmetrically arranged. By the heat exchanger plates thus being stackable, it is possible to ensure, by means of conventional packings and spacers, a desirable gap width and a desirable gap cross-section between the plates. Moreover, a compact and space-saving plate heat exchanger is obtained.

In another preferred embodiment, the surface profile has a profile depth that is considerably smaller than the depth of the protuberances. Thus the surface profile should be so fine that, in contrast to the protuberances, it is capable of breaking up and possibly eliminating the laminar boundary layers next to the heat exchanger plates. The thickness of the laminar boundary layer is unique for each design of the heat exchanger plate, and therefore the heat exchanger plate is adjusted to the fluid to be tempered or to the fluid that is used for tempering, and therefore no dimensions or ratios of the profile depth of the surface profile to the depth of the protuberance can be given. Examples of important parameters are the velocity and viscosity of the fluids.

In yet another preferred embodiment, the surface profile is concavely or convexly arranged relative to the protuberances.

It is also preferred that the geometric transition between the plane of the heat exchanger plate and the protuberances be provided with a radius, and that the surface profile, as mentioned above, consist of spherical or ellipsoid segments. The surface profile, in combination with the protuberances, can thus in these preferred embodiments be said to form a golf-ball-like structure. Owing to the radius in combination with the spherical or ellipsoid shape, the heat exchanger plate does not have any sharp edges or corners which can create dead spaces which conventional cleaning methods cannot reach. This is very important from the aspects of food hygiene, since dead spaces may cause undesirable growth of bacteria and

other organisms. The soft geometry is also favourable from the aspect of forming technology.

According to another aspect, the invention relates to a plate heat exchanger comprising heat exchanger plates with turbulence-promoting protuberances arranged in each heat exchanger plate. The plate heat exchanger is characterised in that each protuberance has a surface profile for promoting break-up of laminar boundary layers, and that said surface profile consists of spherical or ellipsoid segments.

The plates can be arranged in various ways in the plate heat exchanger. For example, the heat exchanger plates can be arranged so that the protuberances in a first heat exchanger plate in connection with stacking are partially accommodated in the protuberances in a second heat exchanger plate. The heat exchanger plates can, for instance, also be arranged in pairs with a first pair of plates and a second pair of plates adjoining the first, in which pairs of plates a first and a second plate are arranged with the protuberances directed away from each other and in which pairs of plates a gap is arranged between the first and the second plate. The latter variant allows that the two fluids used in the plate heat exchanger can be arranged to flow through different gap cross-sections and, thus, obtain different flow patterns.

DESCRIPTION OF DRAWINGS

The invention will in the following be described in more detail by way of example and with reference to the accompanying drawings which illustrate a currently preferred embodiment.

Fig. 1 is schematic view of an embodiment of a plate according to the invention.

Figs 2a and 2b show two examples of stacking of plates in a plate heat exchanger.

Fig. 3 shows a partial enlargement of a protuberance in the plate according to Fig. 1.

TECHNICAL DESCRIPTION

With reference to Fig. 1, a part of a heat exchanger plate 1, henceforth referred to as plate, according to the present invention is schematically shown for use in a plate heat exchanger (not shown). The plate 1 comprises in a conventional manner a plate element 2 with a plurality of protuberances 4 projecting from the plane 3 of the plate. In the embodiment illustrated, the protuberances 4 have the shape of spherical segments. It should, however, be appreciated that also other geometries of the protuberances are conceivable. The main purpose of the protuberances 4 is that they should promote a turbulent flow of a fluid flowing through a gap defined by two adjoining plates 1.

Depending on how the plates 1 are intended to be stacked to form a plate heat exchanger, the protuberances 4 of the plates 1 can be oriented in various ways, which is best appreciated by a person skilled in the art, and thus create different gap cross-sections X, Y, see Figs 2a and 2b.

A highly space-saving plate heat exchanger is obtained, for instance, if the protuberances 4 are symmetrically arranged and designed in such a manner that the protuberances 4 in a first plate 1A are partially accommodated in the recesses 4' formed by the protuberances 4 in a second plate 1B, see Fig. 2a. Between the two plates 1A and 1B a gap is formed, through which the fluids used in the plate heat exchanger can flow. The fluids used in the plate heat exchanger will thus flow through identical, or essentially identical, gap cross-sections X, Y.

The plates 1 can also be stacked in such a manner that the heat exchanger plates 1 are arranged in pairs with a first pair of plates 10 and a second pair of

plates 10' adjoining the first, in which pairs of plates 10, 10' a first 1A and a second 1B plate are arranged with the protuberances 4 directed away from each other, see Fig. 2b. A gap is arranged between the first 1A and the second 1B plate in each pair of plates 10, 10', and between the respective pairs of plates. The gaps form the passages with gap cross-sections X, Y, through which the fluids used in the plate heat exchanger can flow. As a result, the two fluids used in the plate heat exchanger will in this variant flow through different gap cross-sections X, Y.

It should be appreciated that the plates 1 can be stacked in an infinite number of ways, and that the invention should not be limited by on which side of the protuberances 4 the fluids used in the plate heat exchanger flow. It should also be appreciated that the different plates need not have the same geometry of their protuberances.

With reference to Fig. 3, the geometric transition 5 between the plane 3 of the plate 1 and the respective protuberances 4 is arranged with a radius or with a geometry which is soft in some other manner. A soft geometric transition is most important from the aspect of hygiene since plate heat exchangers when used in the food industry require frequent and very careful cleaning. Any sharp geometric transitions may create dead spaces which can form growth zones for bacteria and other organisms. However, it will be appreciated that soft geometric transitions also reduce the flow resistance, which is detrimental to an increased turbulence.

The protuberances 4 may consist of isolated zones, such as spherical or ellipsoid segments, but may also consist of wholly or partly continuous zones in the form of, for example, waves or grooves, i.e. a somehow corrugated surface.

The protuberances 4 are suitably formed by pressing, thus allowing the protuberances to create cup-shaped

bulges. One side of the plate 1 will thus have protuberances 4 while the other side will have corresponding recesses 4'.

The protuberances 4 are provided with a surface profile 6 which is shown more distinctly in Fig. 3. The main purpose of the surface profile is to further facilitate and promote the break-up of the laminar boundary layers next to the plates and, thus, promote or enforce a turbulent flow through all of, or the major part of, the gap cross-sections X, Y.

In its simplest embodiment, the surface profile 6 consists of a number of spherical or ellipsoid segments in the circumferential surface 7 of the protuberance 4. However, it will be appreciated that also other geometries are possible, such as crosses, stars or other prismatic geometries. The number of possible geometries is infinite as a person skilled in the art will realise. The surface profile 6 can thus be concave as well as convex relative to the protuberance 4, or be alternately concave and convex. If the surface profile 6 is concavely arranged, it may be compared to the surface of a golf ball, i.e. the circumferential surface 7 of the protuberance 4 is pitted. If the surface profile 6 is convexly arranged, the circumferential surface 7 of the protuberance 4 can be compared to a granular or "wart-like" surface. Of course, it will be appreciated that by the plate 1 preferably being formed by pressing, one side will obtain a concave surface profile while the other side will correspondingly obtain a convex surface profile. The invention should not be limited by which side faces the fluid that is to be tempered.

The surface profile 6 is formed, as are also the protuberances 4, most easily by pressing, but it may also consist of a surface which is, for instance, etched, or of a profiled laminate. In the latter cases, the "rear side" will be perfectly smooth.

The protuberances 4, together with the surface profile 6, promote not only a turbulent flow by break-up of the laminar boundary layers, but also increase the specific surfaces, i.e. the surfaces exposed to the fluids transported in the plate heat exchanger. The larger specific surface, the higher heat transfer.

The surface profile 6 has a profile depth which is considerably smaller than the depth of the protuberances 4. However, it will be appreciated that the selection of profile depth, profile tightness and orientation depends on factors such as the physical properties of the fluids transported in the plate heat exchanger, for instance rheology and viscosity, the desired degree of turbulence, pressure drop and flow rate. These are factors that are specific to the situation in which the plate heat exchanger is intended to operate. Thus the surface profile must be adjusted to each situation so as to be capable of promoting break-up of the laminar boundary layers and, thus, provide or promote a laminar flow through the entire gap cross-section.

The material of the plates 1 should be a material that is corrosion resistant and suitable for the food industry and that has high thermal conductivity. The selected thickness of the material should be relatively thin for increased heat transfer.

The present invention also relates to a plate heat exchanger (not shown), which is made up of a required number of plates 1 designed as described above. The number of plates 1 depends on, inter alia, the capacity of the plate heat exchanger and will here not be described in detail. The plates 1 can be stacked in various ways, two of which are exemplified in the description with reference to Figs 2a and 2b. Depending on how the plates 1 are stacked, different gap cross-sections X, Y are obtained, and thus different flow patterns for the fluids intended for the plate heat exchanger. The number

of stacking options is large and should not limit the invention.

By means of packings, beads, spacers or the like, a predetermined gap width and a predetermined gap cross-section X, Y between adjoining plates for passage of the intended fluids are ensured.

As an example of the fluid to be tempered mention can be made of milk, juice, soup or purée. As an example of the fluid that is used for tempering, water can be mentioned.

To sum up, the present invention thus comprises plates 1 for use in a plate heat exchanger, and also a plate heat exchanger using such plates. The plates 1 comprise a number of turbulence-generating protuberances 4. The protuberances 4 have a surface profile 6 which promotes break-up of the laminar boundary layers next to the surfaces of the plates 1. The profile depth of the surface profile 6 is adjusted to the intended operating conditions of the plate heat exchanger, but should be considerably smaller than the depth of the protuberance 4 and illustratively form a golf-ball-like structure. The surface profile 6 can be concave as well as convex relative to the protuberance 4. The plate 1, the protuberances 4 and their surface profile 6 together form a surface without sharp geometric transitions which is easy to clean and which thus prevents undesirable growth of bacteria.

The protuberances 4 in combination with the surface profile form a large specific surface, which promotes the heat transfer between the fluids that are transported in the plate heat exchanger. Moreover, the surface profile enhances the turbulence by promoting the break-up of the laminar boundary layers next to the surfaces of the plates, which further promotes the heat transfer.

It will be appreciated that the present invention is not limited to the shown and described embodiments of the plates and a plate heat exchanger made from the same.

The inventive idea can, for example, with minor amendments, be applied to other types of heat exchangers, for instance to tubular heat exchangers in which the tubes included are provided with protuberances which have a surface profile to promote break-up of laminar boundary layers. Several modifications and variants are thus conceivable, and consequently the invention is defined exclusively by the appended claims.